

BIM FOR ADAPTABLE HOUSING DESIGN IN THE CONSTRUCTION INDUSTRY

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ABSTRACT

Residential buildings design has been very much influenced lately by the concept of open building system historically. From the very initial period of modern housing, purpose built houses have often incorporated the future spatial requirements when building cater initially for current spatial needs of residents. These initial designs were done without any serious emphasis on future adaptability. Hence, more creative and innovative perspective on designing residential buildings which will accommodate adaptability is needed to enhance sustainable building performance, through design concept for adaptable residential buildings. The creation of a more sustainable environment can be augmented by adaptable design strategies that produce a level of building flexibility, and which allow for a variety of changes to be accommodated. However, developing a better understanding of how buildings change over time is another issue argued by architects concerned with extending the life of buildings. This paper presents the preliminary literature review of the findings on the techniques and concept to be employed at design stage which provides choice to clients/user and also promote the concept of designing for adaptability and aid design-out-waste from the source respectively. The initial findings outline the benefits that can be obtained by using BIM as a tool to achieve adaptability and waste minimization through designing-for-adaptability. The objective of this paper is to provide insight on adaptability, waste minimization and also Building information modeling. The methodology employed in this paper is based on secondary source, information were collected from various form and reviewed in order to achieve the objective of the study.

Keywords: Design-for-Adaptability, Waste Minimization, Building Information Modeling.

1.0 Introduction

Residential buildings design has been very much influenced lately by the concept of open building system historically. From the very initial period of modern housing, purpose built houses have often incorporated the future spatial requirements when building to cater initially for current spatial needs of residents. These initial designs were done without any serious emphasis on future adaptability. Hence, more creative and innovative perspective on designing residential buildings which will accommodate adaptability is needed to enhance building performance, through design concept for adaptable residential buildings. Adaptable housing appears to be a vital response to rapid change, especially in terms of user demand for more space, as a result of family growth. As Graham (2006) stated, "A sustainable building is not a building that must last forever, but a building that can easily adapt to change"(Eguchi et al, 2009). Thus the creation of a more sustainable environment can be augmented by adaptable design strategies that produce a level of building flexibility, and which allow for a variety of changes to be accommodated. However, developing a

better understanding of how buildings change over time is another issue argued by architects concerned with extending the life of buildings. The lengthening of the life of a house is believed to be useful to reduce the consumption of natural resources and the economic burden of housing expenses for families (Kendall et al, 2011). Therefore, adaptability is inevitable to the future housing of Malaysia.

According to Schmidt et al (2005), time as a design contingency relies on placing architecture in context, making it responsive to its temporal reality and biggest fear - change. Designers tend to ignore these temporal aspects focusing on an aesthetic fixation and functional performance, freezing out time in pursuit of a static idealized object of perfection. A reaction to this way of operating is the encouragement of a more dynamic and long-term understanding of the built environment. How then, does one design for time? (Eguchi et al, 2005).

Adaptability as a design characteristic embodies spatial, structural, and service strategies which allow the physical artifact a level of malleability in response to changing operational parameters over time. (Schmidt et al, 2009) This strategic shift reflects buildings, not as finished work removed from time, but as imperfect objects whose forms are in constant flux continuously evolving to fit functional, technological, and aesthetic metamorphosis in society. According Baldwin (2000), states that the capacity for buildings to respond to these changes are highly determined through design decisions early on resulting in the building's design structure – what it is, how it is constituted (Schmidt et al., 2009). Achieving adaptability then demands a shift away from the current emphasis on form and function in response to immediate priorities, towards a 'context' and 'time-based' view of design.

Adaptability as a design principle which brings to the forefront of this critical path- time, as Croxton (2003) points out, "If a building doesn't support change and reuse, you have only an illusion of sustainability." The exploration of adaptability which includes ideas and findings intertwined with aspects of the Open Building paradigm. The relationship between the Open Building movement and the findings regarding adaptability would be examined and the industry shifting towards a more sustainable and time-based approach to design (Gibb et al, 2010). Following the research strategy undertaken by Schmidt et al (2010), this research also will critically review literature on: (i) adaptability, (ii) Space design, (iii) waste minimization, (iv) Demolition rate. The links between the above four focus areas could provide insight into improving the design of adaptable housing; hence enhance sustainable performance of the building by understanding what parameters are critical and how changes to them can be captured.

The architect therefore has a decisive role to play in devising concepts to reduce waste in construction at all levels by focusing on designing out waste (Rajendran & Gomez, 2012), using the concept of adaptability and BIM as a tool to achieve the objective. However, it will go a long way in enhancing sustainable building performance.

Over decades, the concept of designing residential buildings for adaptability has been neglected with increasing buildings needing to be redesigned for long-term adaptability. However, the evolving needs for more space by the occupant due to social and demographic change in a household cannot be neglected. As Russell (2001) and Moffatt (2001) point out, the world faces resource scarcity and ecological crisis, a concern for the adaptability of buildings is especially relevant, as the existing building stock represents the largest financial, physical and cultural asset in the industrialized world. A sustainable society is not possible until this key resource can be managed sustainably.

Urban areas nowadays, are experiencing problems and issues related to poor use of buildings and high rate of demolition activities increasing day by day, as a result of the occupants and owners needs for more space or rooms, increase in house hold and family members. However, another challenge being faced, as stated by Russell (2001) and Moffatt (2001), is that only few buildings exist today that have been

intentionally designed for adaptability, and put to the test of time (Davison et al., 2006). Traditionally, many designers have preferred to work from the assumption that their buildings will never experience any significant change in future. Hence, there is need to provide occupants with flexible and adaptable choices to fit their dynamic needs for space as it evolves.

This paper focused on design-for-adaptability as a concept for waste minimization using BIM as a tool in the construction industries.

1.1 Changing User Requirement

In a society marked by constant change, it is difficult to make accurate assertions or prediction. According to Friedman (2002), forecasting future demographic tendencies and identifying technologies that will revolutionize industries or naming lifestyle trends that will predominate a particular generation are challenging and sometimes very critical. Forecasting with any precision on how homes will be designed and constructed in the future is no exception. However, we can anticipate that homes will continue to reflect the tastes, habits, and lifestyles of the people who inhabit them and they will be influenced by new technologies yet to be introduced. As the pace of change in society inevitably accelerates and intensifies so will the forces acting on how we occupy, utilize and modify our dwellings (Friedman, 2002).

Long term strategies are necessary to keep the building stock up to date, even if user demands increase over time and changes in user requirements will demand flexibility to satisfy the evolving challenges in future (Gijbers, Lichtenberg, & Erkelens, 2008). However, the adaption of shelters or homes by their residents to suit their varying needs has always been part of human habitation (Friedman, 2002). Gradual modifications happened over a long period of time. Physical changes such as the demolition of a partition wall or the addition of another level were limited to the constraints of the dwelling itself, the available space and the skills of the designer or builder (Friedman, 2002). As time progresses, the factors and decisions that shaped the original design become increasingly out-dated, a process of response to change either in the lives of the occupants or in the state of technological innovation which begins upon occupancy and brings about some relevant condition to the need for spatial changes in homes.

If user requirements are expected to increase over time, the importance of improvement of the level of functionality in the initial building design is of great paramount. The supplied functionality is, therefore larger and the decrease may be less substantial (see figure 1 below). User requirements change during the lifespan of building, new demands evolves due to various factors Friedman et al., (2002); Gijbers et al., (2008). People roughly spend 80% of their time inside buildings; logically the user always looks for the solution that meets his/her evolving demands best (Gijbers et al., 2008).

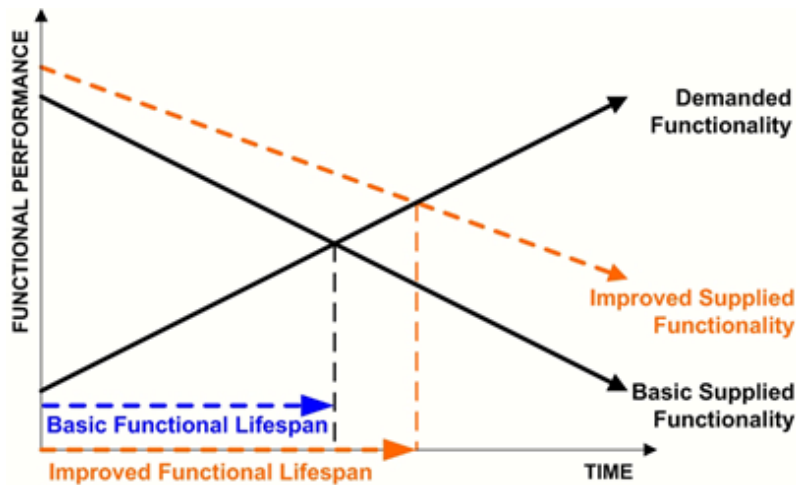


Figure 1: Improved functional lifespan (adapted from (Gijsbers et al., 2008).

In the industry, it is common practice that products are (re)developed to perform according to the wishes and demands of the intended user. However, by not fulfilling these demands, it results to problems, such as disappointing sales results and failure in the competitive market, (Gijsbers et al., 2008) Strangely enough, the exact opposite occurs in the building industry.

According Blok & van Herwijnen, (2006) high structural flexibility will increase the building's performance by allowing for possible future adoptions of the building layers, for example caused by changing user requirements (Gijsbers et al., 2008). The types and terms of change of user requirements in buildings are characterized and illustrated in Table (1) and Figure (2) below as follows:

Lifespan (Year)	Types of Change	Term of Change	Aesthetic Upgrade	Functional Change	Spatial Upgrade	Functional Upgrade	Technical Upgrade
0	Trend	Everyday					
1	Changes in spatial purpose	≥ 1 year					
5	Adaptation for functional use	≥ 5 year					
5	Upgrade of interior finishing	≥ 5 year					
10	Change of function	≥ 10 year					
5	Upgrade the level of comfort	≥ 15 year					
15	Functional upgrade	≥ 15 year					
30	Technical upgrade	≥ 30 year					

Table 1: Types of change of user requirements, terms of change and characteristics (Dobbelsteen, 2004)

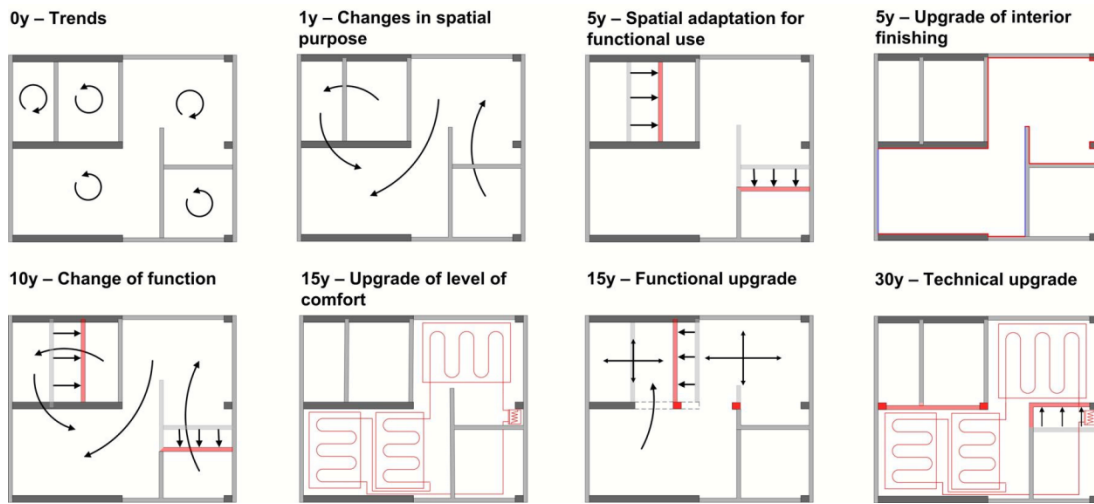


Figure 2: Types of change of user requirements in exemplary floor plan
 (Adapted from Gijbers et al; 2008)

1.2 Adaptations to the building

The building has facilitated the clients' long term plans, with the concept of adaptable design approach, by allowing all the changes and providing the ability to grow in different phases. The grid adopted coordinates the abundance of moving, portable, changeable and repeatable parts, which has a clear value in giving flexibility to the whole scheme. It also has enabled a neater appearance of the internal space and prevented from the chaos of such a changing, busy and noisy factory. The repetition of parts has also helped through all the process and the extensions have been easier due to the previous experience (Fuster, Gibb, & Austin, 2009)

(Fuster et al., 2009) states that the pods -designed to change from place to place, to remain close to the ongoing operations in the factory- have almost never been moved and remain now static, as the space is completely full of machinery. In fact a new extension is actually undergoing and a factory building of more than half the actual will be linked to the existing four squares. There will not be any more pods and the offices are going to be fixed. At this new stage, some areas could have been improved, but finally not radical changes have happen as the new building must keep the ability to interchange its parts with the existing one. it has been a very good investment and given the company a significant value by allowing them to accommodate the ever changing business needs and grow when necessary (Fuster et al., 2009).

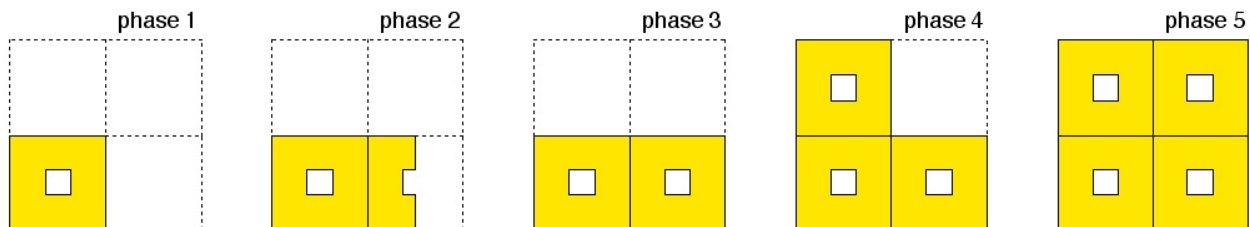


Figure 3: Igus factory growing sequence (Grimshaw) (Fuster et al., 2009).

2.0 Waste:

Waste can also be seen as a by-product of an activity or process that is no longer of value to the owner who sees it as waste, but could also be seen as a resource by another (Powell, 2009). After categorizing waste to seven types by Ohno (1994), Womack and Jones (1996) defined waste as any activity that absorbs resources and does not have any value adding (Rajendran & Gomez, 2012). According to Formoso et al. (2002), waste is the loss of any kind of sources-materials, time (labor and equipment), and capital-produced by activities that generate direct or indirect costs but do not add any value to the final product from the point of view of the client.

2.1 Construction waste

Construction is one of the important sectors which influence the economy of our country. Construction waste origins are related to design changes, leftover material scraps, no-recyclable/re-useable packaging waste, and design/detailing errors (Rajendran et al., 2012). Construction waste management may be defined as the discipline associated with the control of generation, recovering, processing and disposal of construction wastes in a manner that is in accord with the best principles of human health, economic, engineering, aesthetics, and other environmental considerations (Rajendran et al., 2012). Construction waste management plays an important role in the management of construction waste. It is however evident that there is a lack of emphasis on the aspect of managing waste at the design stage.

2.2 Waste minimization

Waste minimization is defined any technique which avoids, eliminates or reduces waste at its source (Key, A., 2000). According to Crittenden and Kolaczowski (1995), many related terms are used to describe waste minimization in different 'fields' or countries.

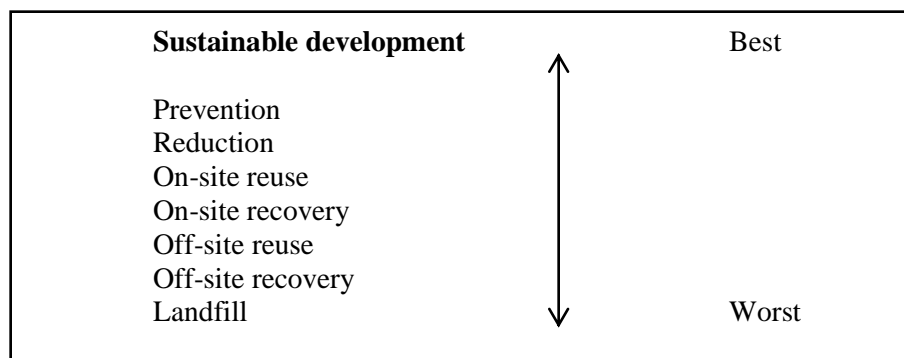


Figure 4: The Wastes Hierarchy

2.3 Concept of designing-out-waste

Waste minimization is any technique that either avoids, eliminates or reduces waste at its source (Kolaczowski 1995). Many different terms are used to describe the various waste minimization techniques; the focus however, with this research is on 'source reduction' techniques opposed to 'release reduction' techniques. Release reductions often involve activities dealing with pollution after its

generation (Keys et al, 2000). However in another statement by Keys et al (2000) states that the best management approaches to waste, particularly hazardous waste is to manage the process so that there is no waste to manage. Furthermore, designing out waste at the earliest stages of the construction process offers the greatest fundamental opportunities for waste minimization. This is obviously very difficult, but the concept of ‘designing out waste’ begins with the question as posed by Keys et al (2000): Can the amount of waste being produced be minimized, if not eliminated?

2.4 Waste minimization through design

Design decisions ultimately determine the waste stream characteristics. Additionally, the design of a product or system will also determine the route of disposal. For example, whether a material can be separated, recovered or reused. A commonly used term, particularly in the US, for considering environmental issues in design is ‘Design for Environment’ (DFE). DFE is a process of minimizing environmental impact (including waste) without sacrificing function and quality. The application of environmental design approaches into the project process can be distinguished by degrees of innovation (Keys et al., 2000). Brezet describes the four types of eco-design as:

- Type 1 – product innovation
- Type 2 – product re-design
- Type 3 – function innovation
- Type 4 – system innovation

Fig 5: *Source adapted* (Keys et al., 2000)

The majority of eco-design innovation is focused on types 1 and 2 innovations. Type 3 Innovation could be described as abandonment of building services towards natural ventilation strategies (Keys et al., 2000). Type 4 innovation would address the whole technological system and probably question the need for the building. Whichever innovative strategy one adopts it is essential to understand the fundamental elements of the problem. One must identify the route of the waste, whether its origins are in concept, scheme or detail design and what disciplines are involved (Keys et al., 2000). It is then necessary to adopt a waste reduction approach (figure 6 below) to address the cause of the issue. Finally, the process of designing out waste must be integrated within the project process to ensure its success.

- ❖ Use of prefabrication and off-site prefabrication
- ❖ Standard component
- ❖ Realistic component size, capacity and specification
- ❖ Minimizing temporary works
- ❖ Optimizing design lives
- ❖ Allowing specification of recycled materials in design
- ❖ Designing for recycling and ease of disassembly
- ❖ Identification of materials/products which create waste
- ❖ Poor communication

Fig 6. *Short and long term designing out waste approaches adapted from* (Keys et al., 2000)

However, it is evident that various literatures consulted recognized the notable role of architects and designers in facilitating waste reduction sector-wide (Dainty et al., 2004; Osmani et al., 2007; Brewer et al., 2008; & Osmani et al., 2008). There is a general consensus in the literature that design changes

“rework” during the construction process are major source of construction waste (Keys et al., 2000; Osmani et al., 2007; Osmani et al., 2008). Furthermore, in another perspective, reworking original drawing or plan by engaging in demolition activities to upgrade comfort level as a result of either change in social status or level of income. Research undertaken by Faniran and Caban (1998), ranks design changes as the lead waste source in the Australian construction industry. It has been estimated that 33% of on-site construction waste is a direct result of the architects failure to implement waste reduction measures during the design stage (Keys et al., 2000) with initial design decisions potentially accounting for one third of all waste production throughout the lifetime of a project.

3.0 Building Information Modeling (BIM)

BIM is a business process supported by technology. To optimize the use of the technology it is necessary to deploy the process. It is absolutely critical to understand this as in the construction industry, traditional methods use technology in isolation, but the BIM process uses technology in collaboration (CREAM, 2011). Hamed defines BIM as an approach to building design that that involves the use of a digital building model created from coordinated, consistent design information enabling whole-building analysis, faster decision-making, and better documentation (Golzarpoor, 2010). BIM software offers many benefits for general building design. State-of-the-art BIM software uses a centralized, parametric model—where all the plans and sections, the quantity takeoffs, and other related documentation are —live views of the model and are automatically coordinated by the software.

Building Information Modeling (BIM) is defined as the parametric modeling of a building. Simply stated BIM allows the project team to virtually design and construct the building. BIM is not only a technological innovation, but also a significant shift in the overall design process (Rajendran & Gomez, 2012). According to Brad Hardin BIM is a digital representation of the building process to facilitate exchange and interoperability of information in digital format (Hardin, 2009). The resolution to adopt new technologies that encouraged collaboration becomes inevitable see figure 7 below.

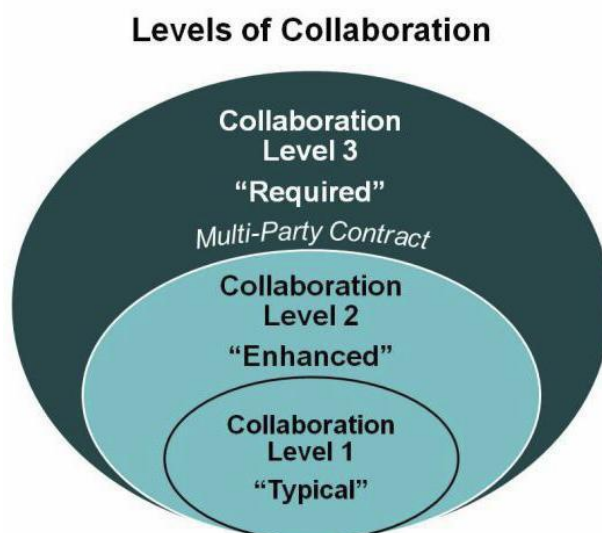


Fig. 7 Levels of collaboration (CREAM, 2011)

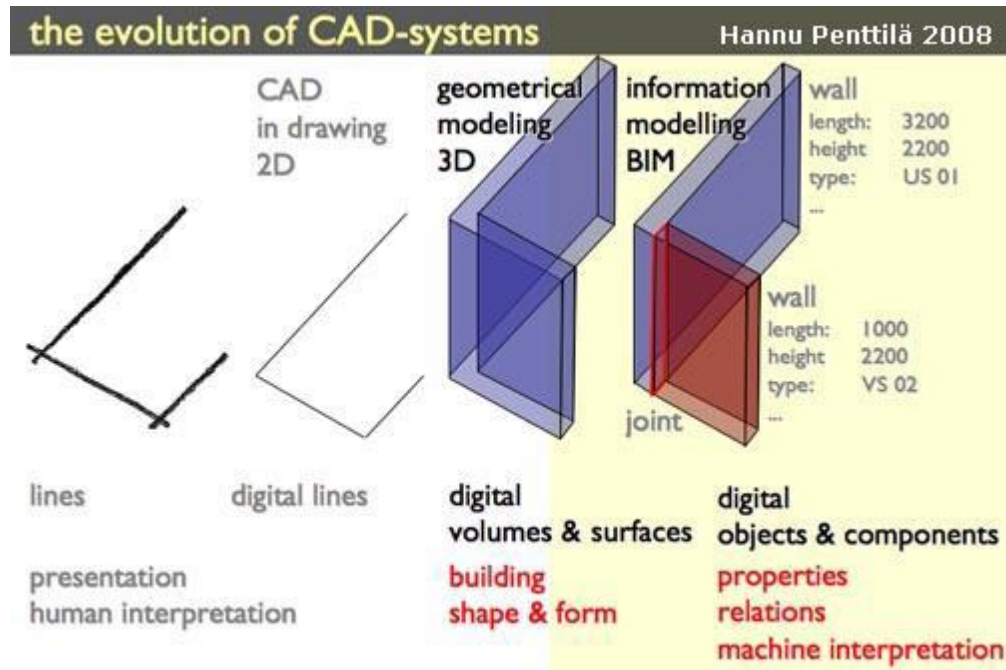


Fig 8: The evolution of CAD-Systems (CREAM, 2011)

3.1 BIM Evolution

Design took a major step forward with advanced CAD systems the 2D versus 3D debate that has been deliberated for two decades in construction (CREAM, 2011) being resolved completely in favor of 3D within 18 months of inception as shown above in fig. 8. And fig. 9 below shows a brief history of BIM.

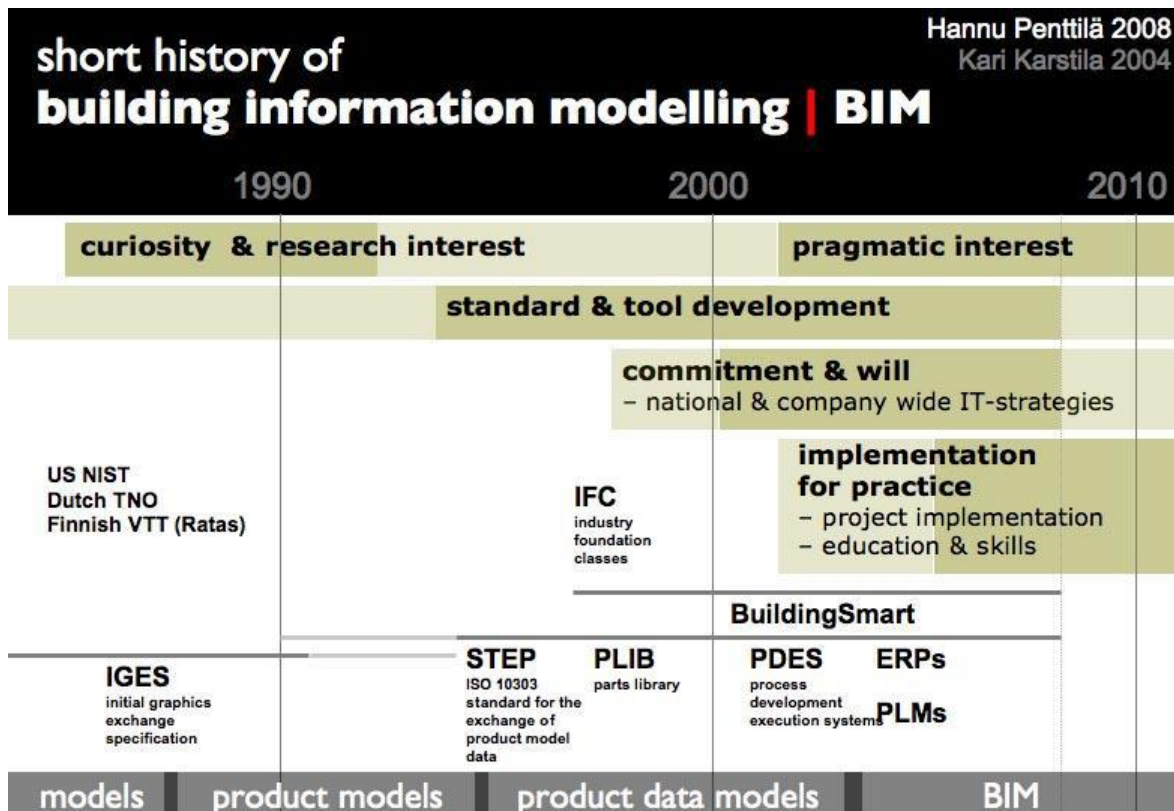


Fig. 9 Brief history of BIM (CREAM, 2011)

3.2 Benefits of BIM

BIM is a revolutionary technology and process that has transformed the way buildings are designed, analyzed, constructed and managed. BIM has become a proven technology (Hardin, 2009), BIM as a technology is no longer in its fancy and has started to yielding results for most architectural and other allied firms all over the world. The technology facilitates virtual construction of a facility(Hardin, 2009) whilst complete building documentation process to shift from architectural drawings into a computerized models. Below are some of the benefits exhibits by the BIM technology (Hardin, 2009; Golzarpoor, 2010;Keys, Baldwin, & Austin, 2000; Arayici et al., 2011; Rajendran & Gomez, 2012))

- ❖ A valuable project management tool
- ❖ Automatically provide shop/coordinated drawings
- ❖ Build fundamental intelligence into drawings
- ❖ Facilitate off-site pre-fabrication
- ❖ Improve field coordination and significantly reduce interferences
- ❖ Improve project tracking process
- ❖ Provide a single database of information
- ❖ Provide automated bills of material and quantities
- ❖ Provide seamless flow of information
- ❖ Provide visualization effect of a project
- ❖ Save cost and time at every phase of design and construction
- ❖ efficient material ordering and effective site management

However, some of the benefits as stated in a presentation by CREAM (2011), BIM as an integrated process allows professionals to explore a project's key physical and functional characteristics digitally – before it is built. Hence, use coordinated and consistent information to:

- ❖ *Design* innovative projects from the earliest stages
- ❖ *Visualize, simulate & analyze* real-world appearance, performance, and cost
- ❖ *Document* accurately
- ❖ *Deliver* projects faster, more economically, and with reduced environmental impact (CREAM, 2011)

3.4 Reducing Rework

The problems related to rework are fixed early in the design and hence minimize the effect and waste attributed to reworking design either as a result of client decision or technical difficulties with respect to constructability and buildability related issues. Any design changes inputs into the building model are automatically updated. Hence, there will be less rework due to possible drawing errors or omissions. Reducing rework is highly significant and BIM aid and facilitate in achieving it.

3.5 Use of BIM for Adaptable Housing Design in Minimizing Waste.

The challenge being faced today in our society is the static nature of our residential buildings; highly level renovation with high impact demolition activities in search of comfort becomes inevitable. Hence, BIM can aid in projecting in virtual image the future adaptability activities to occur, so as to avoid, reduce or eliminate the future waste. Waste is mostly induced into the environment before measures are taking to minimize the impact. In this research, the reverse is the case, the researcher seeks to implore the concept of designing out waste from the sources within the principles of waste minimization “Avoid, reduce and eliminate”, using the concept of adaptable housing. Another challenge faced is to provide a solid foundation for the next generation with tools and techniques that will identify and resolve the fundamental causes and origins of construction waste. The basis for such an approach could utilize Building Information Modeling (BIM) and related technologies, in particular Virtual Prototyping, to provide a platform for ‘virtual’ waste evaluation which reviews and assesses the degree of waste generation throughout all stages of the construction project lifecycle. Although BIM design methods are not currently as fully utilized in the construction industry as in other industries, there is general recognition that BIM adoption will become more pronounced to demonstrate not only the entire building life cycle but also assess an evaluate the environmental performance an impacts of buildings.

5.0 Conclusion

It is evident that BIM is getting wide acceptance swiftly, and the construction industries are trying hard to get more acquainted with the technology so as to improve their level of productivity. Allied professionals in the industry are realizing the benefits of BIM more often and eventually the majority of the industry will migrate towards the technology. Therefore, BIM should be implemented early in the conception stage of design, it will aid to “reduce” waste which as a result of technical errors, “avoid” over specification of material and “eliminates” defects, future reworking of as-built plan, delay, hidden time waste and lack of understanding among “team” players in the construction industry. Therefore, it is necessary to promote BIM in the construction industry in order to play a vital role in the decision making process during the

design stage

This research only considered design aspects “adaptable design” as a concept of minimizing waste from its source; however, there are other areas that could contribute to minimizing waste, such as more exploration of design concept and BIM for construction processes, material management or minimization, and planning. BIM exploration can provide great choice to clients by visualizing the future potential adaptable zones and possible measures to be taken. It is recommended that architects and designers should explore and adopt BIM in early stage of design conception to minimize waste. Further research should be carried out in other stages of construction projects in order to enrich and better enhance knowledge in minimizing waste by implementing from among various techniques which avoids, eliminates or reduces waste at its source as principles of waste minimization.

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